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Kimiabeigi

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(54) **ROTOR ARRANGEMENT AND
ELECTROMECHANICAL TRANSDUCER
HAVING NON-PARALLEL PERMANENT
MAGNETS**

USPC 310/46, 51, 152, 156.01–156.84;
29/596, 298, 732, 428, 607
See application file for complete search history.

(71) Applicant: **Mohammad Kimiabeigi**, Sheffield (GB)

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(72) Inventor: **Mohammad Kimiabeigi**, Sheffield (GB)

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(73) Assignee: **SIEMENS
AKTIENGESELLSCHAFT**, München
(DE)

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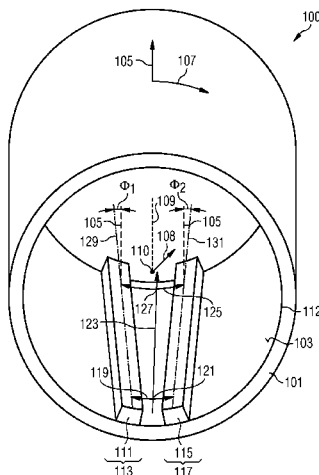
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H02K 37/10; H02K 41/03; H02K 2201/06;
Y10T 29/49009; Y10T 29/49012

(57) **ABSTRACT**

A rotor arrangement includes a support structure providing a mounting surface extending in an axial direction and a circumferential direction. The support structure is adapted to rotate around the axial direction. A first permanent magnet system is arranged at the mounting surface at a first circumferential region. A second permanent magnet system is arranged at the mounting surface at a second circumferential region. A circumferential distance between the first magnet system and the second magnet system at a first axial position differs from the circumferential distance between the first magnet system and the second magnet system at a second axial position.

17 Claims, 6 Drawing Sheets



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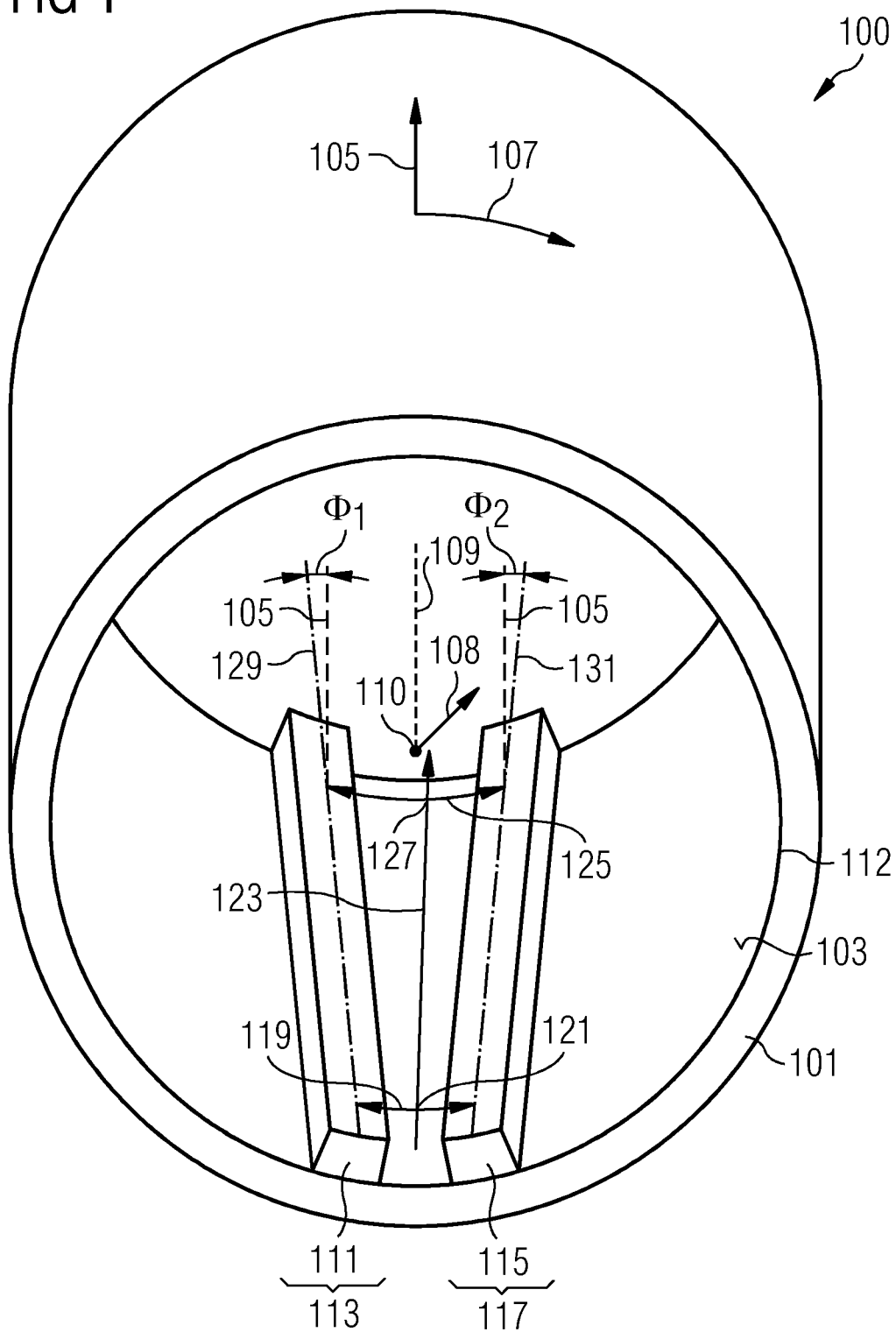
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FIG 1



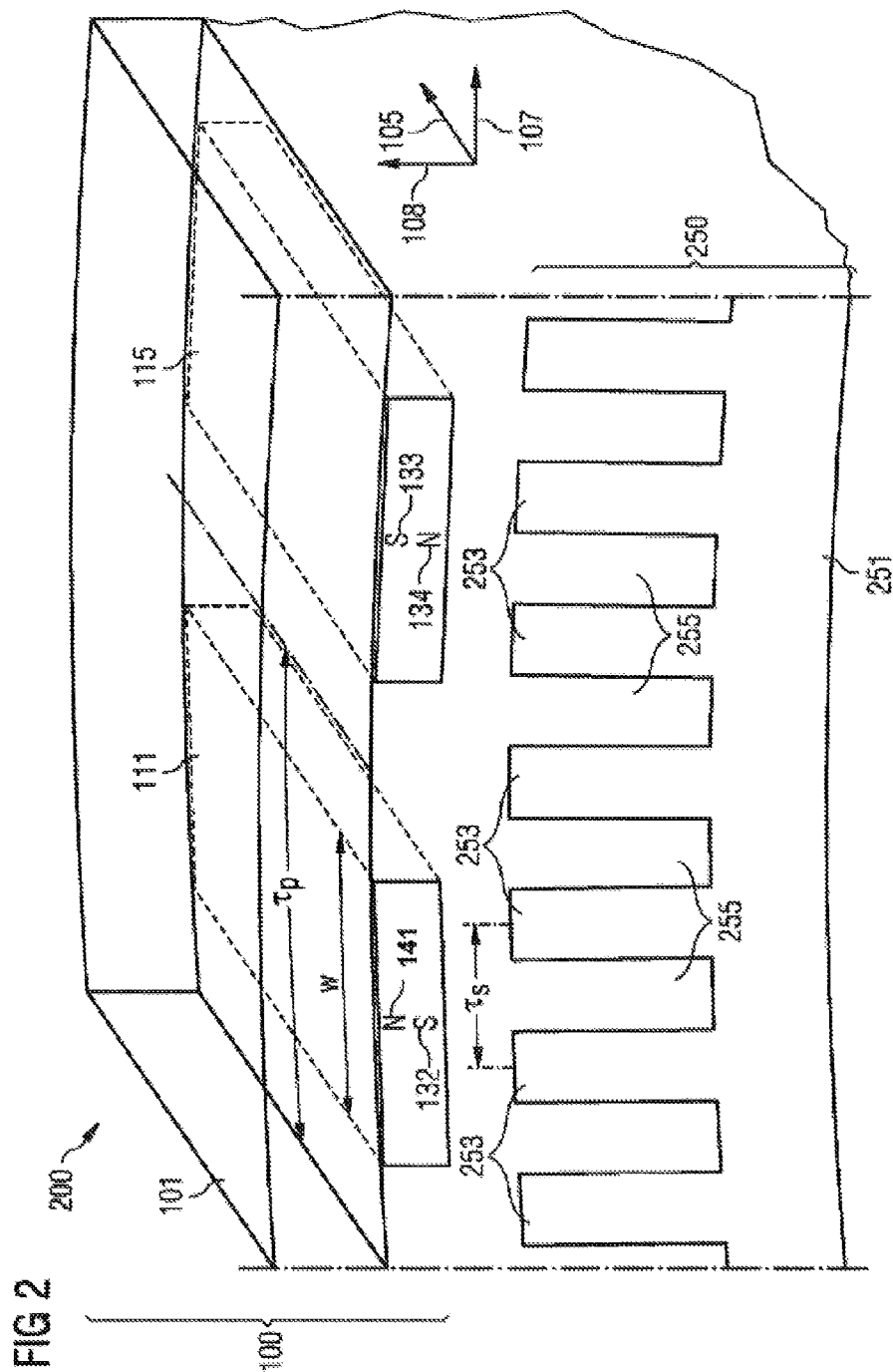


FIG 3

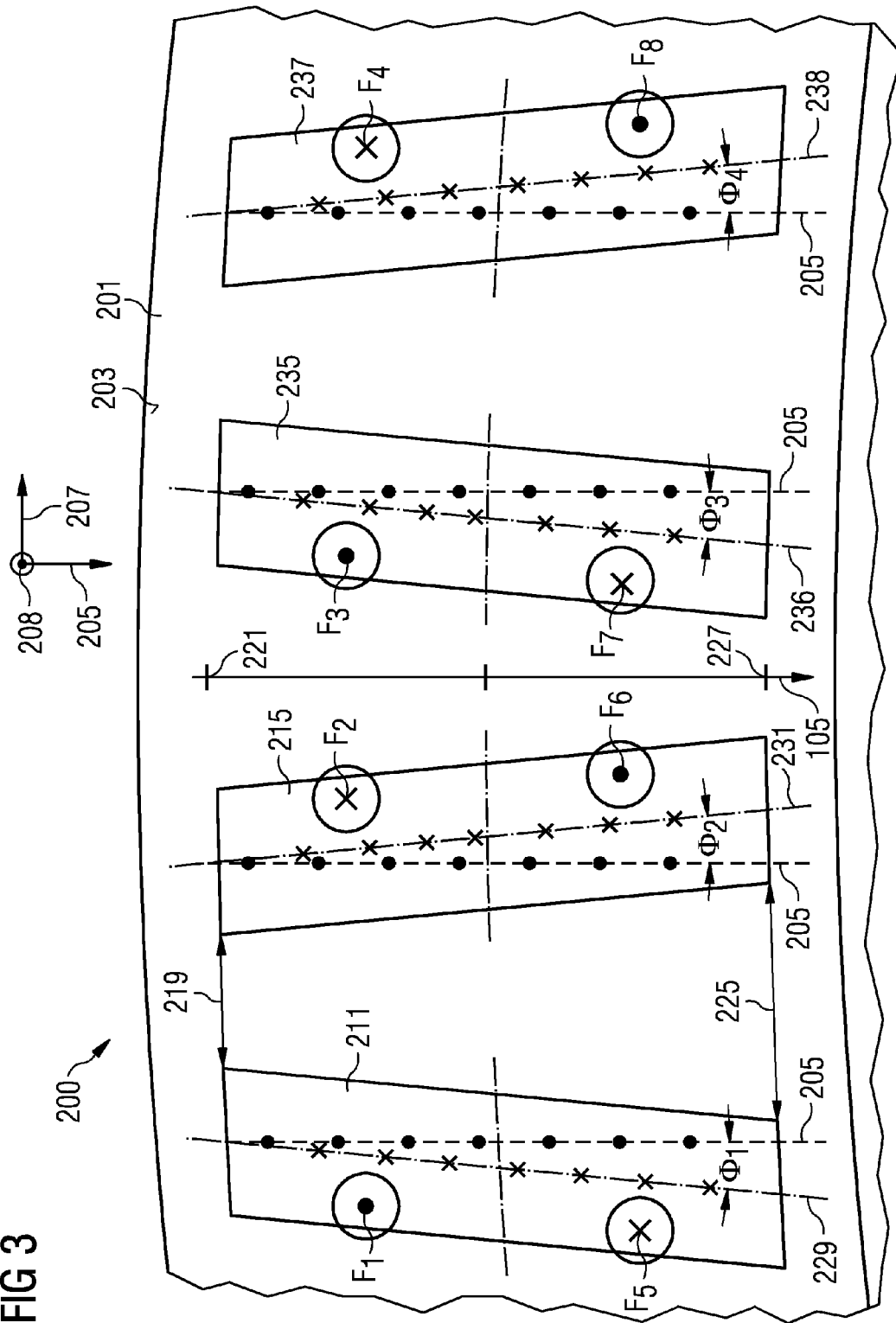


FIG 4

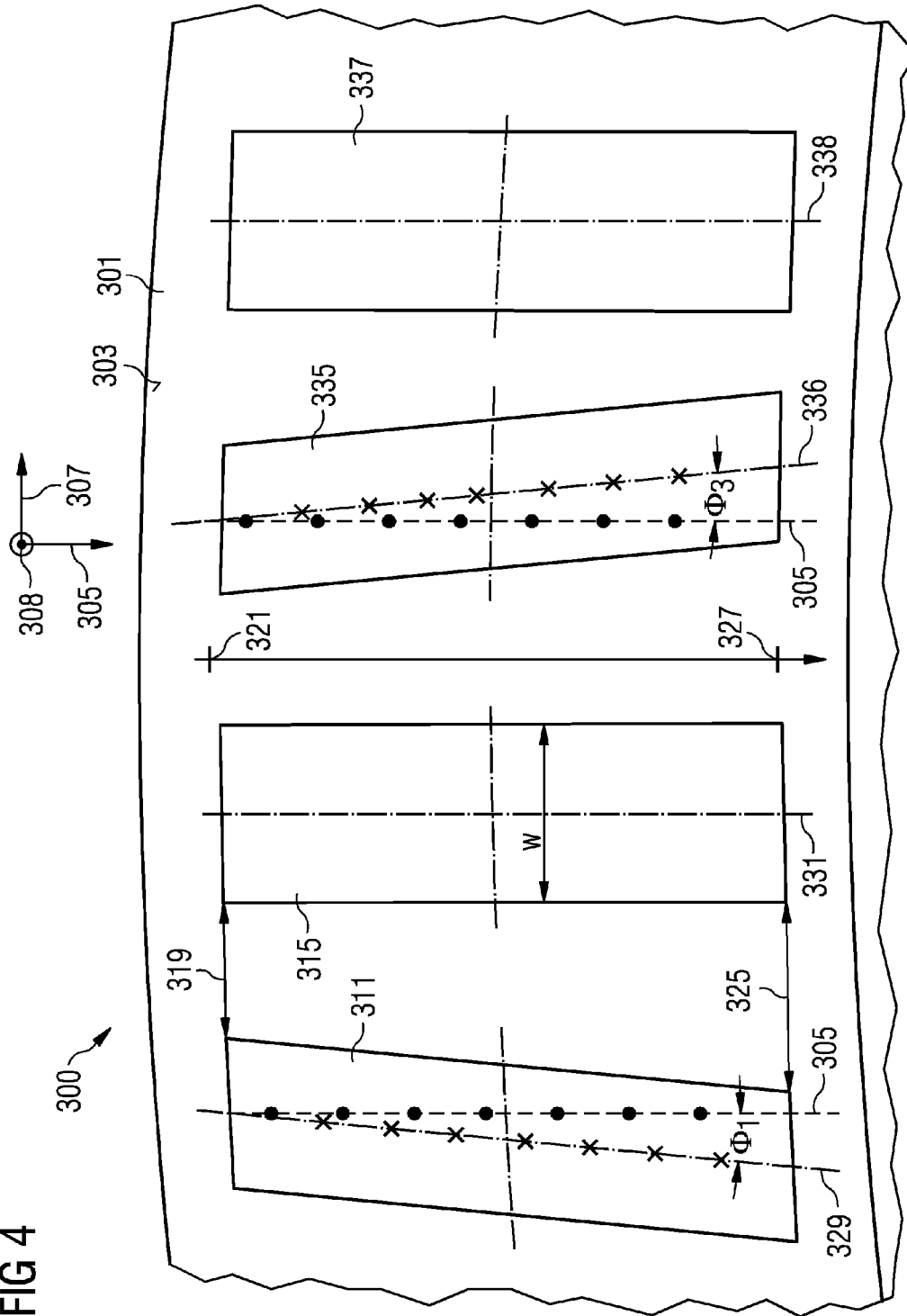


FIG 5

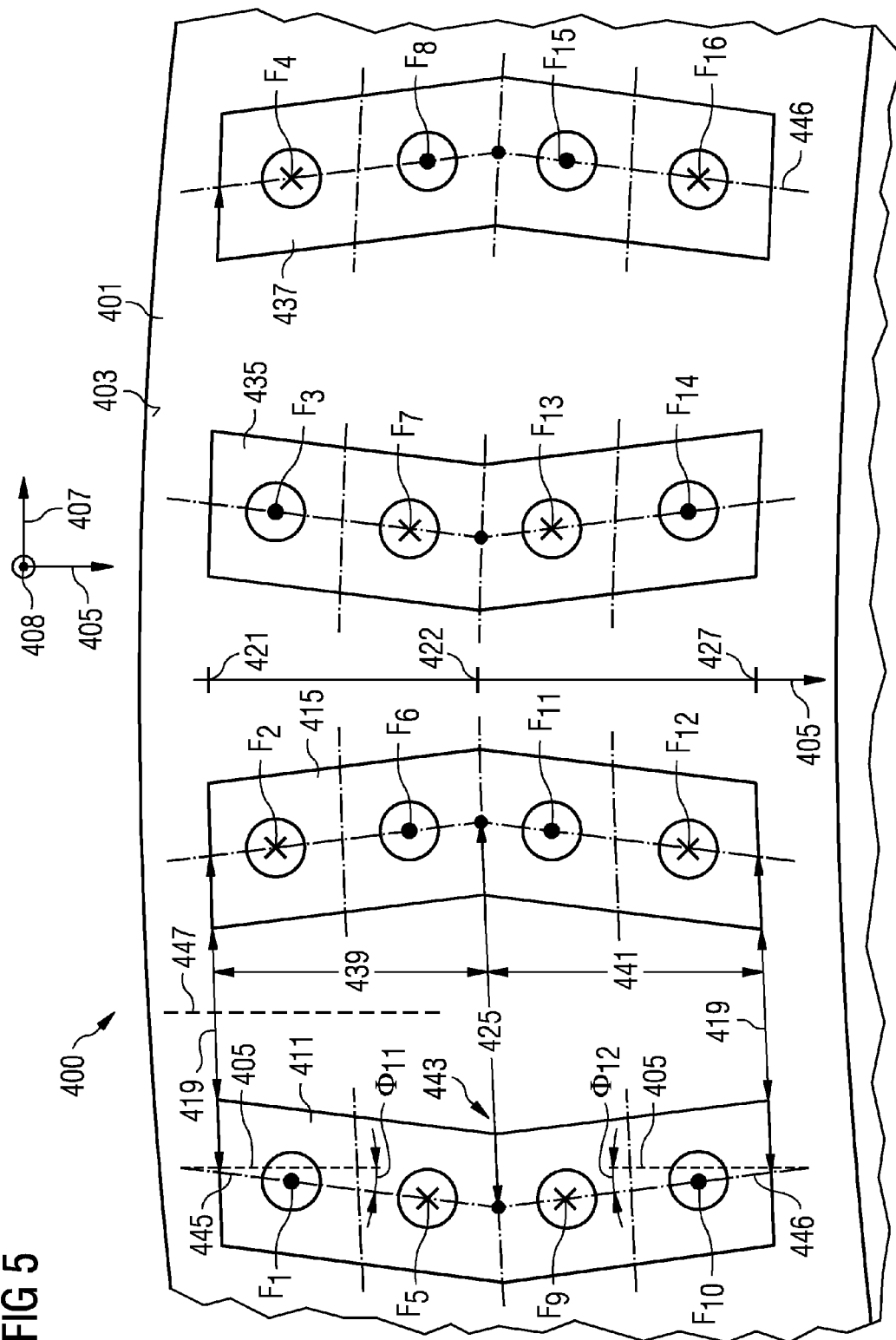
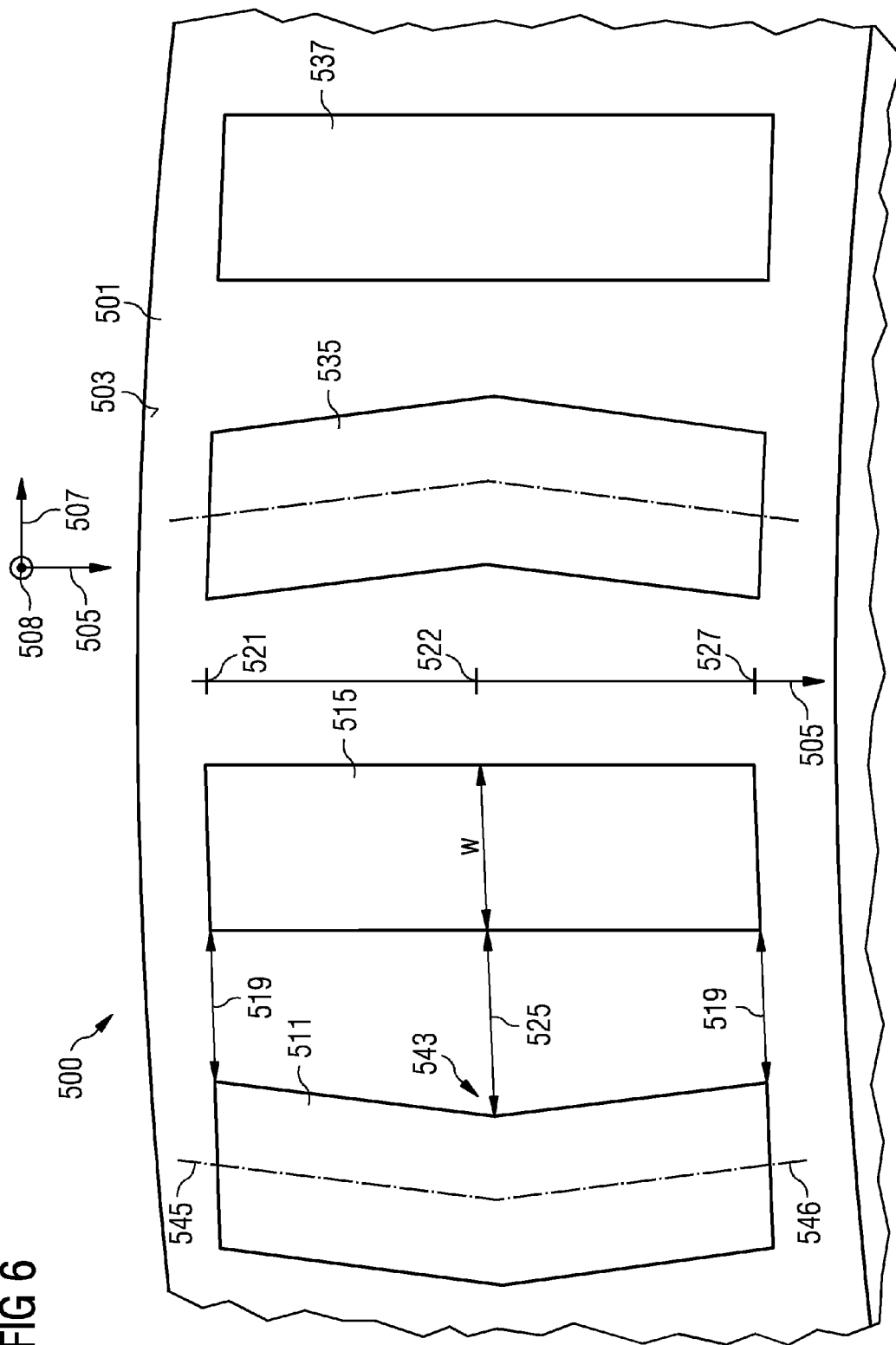


FIG 6



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ROTOR ARRANGEMENT AND ELECTROMECHANICAL TRANSDUCER HAVING NON-PARALLEL PERMANENT MAGNETS

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority to European Patent Office application No. 12164938.8 EP filed Apr. 20, 2012, the entire content of which is hereby incorporated herein by reference.

FIELD OF INVENTION

The present invention relates to a rotor arrangement and to an electromechanical transducer, in particular a generator, wherein permanent magnets are arranged in a non-parallel manner skewed or inclined relative to an axial direction.

BACKGROUND OF INVENTION

An electromechanical transducer, such as an electro motor or a generator converts mechanical energy (in particular rotational energy) into electrical energy or vice versa. Thereby, a stator portion may comprise annularly arranged teeth around which conductors are wound to form plural annularly arranged coils. In particular, the teeth and the coils may be arranged in a cylindrical configuration.

A rotor arrangement may rotate around an axis at the center of the circle relative to the stator portion. The rotor arrangement may comprise plural permanent magnets or permanent magnet systems. Upon rotation of the rotor arrangement relative to the stator, voltages may be induced in the coils due to the moving permanent magnets. The induced voltages may provide electric energy.

In the electromechanical transducer or in the electrical machine a number of vibrations or vibrational modes may occur during operation. The vibration may be due to the interaction of the magnetic flux waves with the stator slotting, i.e. cogging torque. A conventional method to reduce such vibration, in particular torsional vibration, is to skew or incline the magnets with respect to the axial direction with an appropriate skew angle which may be based on the tooth pitch of the stator portion.

However, it has been observed that the conventional electrical machine or conventional electromechanical transducer or conventional rotor arrangement used for an electromechanical transducer is not capable to reduce all kinds of vibration occurring during operation appropriately. In particular, the conventional electromechanical transducer may still exhibit a significant axial vibration during operation.

There may be a need for a rotor arrangement and for an electromechanical transducer, in particular generator, wherein vibration of the electromechanical transducer is reduced and wherein in particular a reduced axial vibration occurs.

SUMMARY OF INVENTION

The need is satisfied by the subject matter of the independent claims. The dependent claims specify advantageous embodiments of the present invention.

According to an embodiment of the present invention it is provided a rotor arrangement, comprising: a support structure providing a mounting surface extending in an axial direction and a circumferential direction, the support structure being

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adapted to rotate around the axial direction; a first permanent magnet system arranged at the mounting surface at a first circumferential region; a second permanent magnet system arranged at the mounting surface at a second circumferential region; wherein a circumferential distance between the first magnet system and the second magnet system at a first axial position differs from the circumferential distance between the first magnet system and the second magnet system at a second axial position.

The rotor arrangement may be used in an electromechanical transducer, such as an electromotor or an electric generator. The electric generator may in particular be used for a wind turbine in order to convert the mechanical energy resulting from impact of wind onto plural rotor blades to electrical energy which may then be supplied to a utility grid, which may then in turn provide the electrical energy to a plurality of consumers.

In particular, the rotor arrangement may constitute a circumferential section from which an annular rotor arrangement may be assembled. Alternatively, the rotor arrangement may represent a complete annular structure, in particular a cylindrical structure having as a principal (cross-sectional) shape a circular shape.

The support structure may be provided for supporting or holding or mounting the permanent magnet systems. The axial direction may correspond (or may be parallel) to a rotational axis around which the rotor arrangement is intended to be rotated during operation, when the rotor arrangement is used for or assembled into an electromechanical transducer. The circumferential direction is perpendicular to the axial direction and a radial direction is perpendicular to the axial direction and also perpendicular to the circumferential direction.

In a complete annular rotor arrangement plural permanent magnet systems may be arranged side by side along the circumferential direction in order to be evenly spaced apart and in order to be distributed evenly around the entire circumference, i.e. the circular circumference of the complete rotor arrangement. In particular, the rotor arrangement may be either an outer rotor arrangement, in which the rotor arrangement is intended to be arranged radially outwards from a stator portion, or may be adapted as an inner rotor arrangement, which is intended to be arranged radially inwards relative to a stator, when assembled into an electromechanical transducer.

The first (and/or the second) permanent magnet system may either be constituted by a single integrally formed magnet or may be constituted by a plurality of individual magnets which are arranged side by side, in particular adjacent to each other, along the axial direction or along a direction inclined relative to the axial direction. The first permanent magnet system as well as the second permanent magnet system may be fixed to the mounting surface using appropriate fixing equipment, such as screws or bolts.

In particular, the first permanent magnet system may be assigned a first main extension direction being the direction along which the first permanent magnet system extends. Thereby, the main extension direction may be defined by a straight line, which best fits plural cross-sectional centers of plural axial cross-sections of the first permanent magnet system. Thereby, the cross-section center may be in particular defined as a geometrical cross-sectional center or a mass center or magnetic center of the considered axial cross-section of the first permanent magnet system. In particular, the first main extension direction of the first permanent magnet system may either be parallel to the axial direction or may be inclined relative to the axial direction by a skew angle defin-

ing a deviation of the first main extension direction in the circumferential direction with respect to the axial direction.

A second main extension direction may also be assigned to the second permanent magnet system in an analogous way. In particular, the second main extension direction may be parallel to the axial direction or may be inclined relative to the axial direction by (in particular another) skew angle defining a deviation of the second main extension direction in the circumferential direction from the axial direction.

In particular, the first permanent magnet system and the second permanent magnet system may be arranged at the mounting surface such that the first main extension direction is not parallel to the second main extension direction. The distance between the first magnet system and the second magnet system at a particular axial position may relate to a distance between the cross-sectional center of the first magnet system and the cross-sectional center of the second magnet system at the considered axial position or may relate to a distance between an edge of the first magnet system and an edge of the second magnet system. Further, the distance between the first magnet system and the second magnet system may relate or may be equal to a distance between a magnetic center of a cross-section of the first magnet system at the considered axial position and a magnetic center of a cross-section of the second magnet system at the considered axial position.

Due to the different circumferential distances between the first magnet system and the second magnet system at the first axial position and the second axial position, respectively, the first magnet system and the second magnet system do not run parallel to each other, in particular the first main extension direction does not run parallel to the second main extension direction.

With such an arrangement of the first permanent magnet system and the second permanent magnet system a torsional vibration of an electromechanical transducer may be reduced, while no significant axial vibration is caused. In particular, the first permanent magnet system and the (circumferentially adjacent) second permanent magnet system may form a magnet pole pair.

According to an embodiment of the present invention the first permanent magnet system is inclined with respect to the axial direction in the circumferential direction, in particular by a skew angle, wherein the second permanent magnet system is inclined with respect to the axial direction in an opposite circumferential direction, in particular by the skew angle.

In particular, the first main extension direction of the first permanent magnet system may be inclined with respect to the axial direction in the circumferential direction and in particular the second main extension direction of the second permanent magnet system may be inclined with respect to the axial direction in an opposite circumferential direction. Further, the inclination relative to the axial direction may have a same amount but may have different sign, i.e. when the first permanent magnet system is inclined by an angle $+\Phi$ relative to the axial direction the second permanent magnet system may be inclined with the angle $-\Phi$ relative to the axial direction.

In this particular configuration or arrangement of the permanent magnet systems the tangential force component due to magnet flux interaction with the stator slotting may be balanced out along the axial length, resulting in zero or very small net resultant force in the tangential (circumferential) direction, minimizing the torsional vibration and acoustic noise emission. Thus, forces acting on the first permanent magnet system in the radial direction may be cancelled out when summing all forces along the extension of the first permanent magnet system. Further, also all forces, in particu-

lar radial forces acting on the second permanent magnet system may be cancelled out, when summing all forces along the extension of the second permanent magnet system.

In addition and in particular in contrast to a conventional system, also the forces exerted on the (neighbouring or adjacent) first permanent magnet system and the second permanent magnet system at a particular axial position may cancel out due to the inclination of the first permanent magnet system and the second permanent magnet system in different directions relative to the axial direction. I.e., when considering a particular axial position, the (radial) forces acting on the plural magnet system of the rotor arrangement may cancel out, when summing along the circumferential direction (over at least two or plural magnet systems). Thereby, a global axial vibration of the rotor structure may be reduced. In particular, a circumferential mode of order "1" or a vibration according to a circumferential mode of order "1" may be reduced, since the excitation forces of all permanent magnets in the circumferential direction do not have the same orientation anymore (i.e. either all pointing radially outwards or all pointing radially inwards) but have alternating orientations, such that one force at the first permanent magnet system may point radially outwards and the force acting on the second permanent magnet system may point radially inwards, such that a net force of zero results, when summing around or along the circumferential direction.

Thus, a lower order vibration mode (i.e. the circumferential vibration mode of order "1") may be reduced, which may increase the stiffness of the structure, in order to reduce vibration amplitude and acoustic noise emission. Further, a (1, 1) vibration mode, the first element indicating the circumferential mode and the second element indicating the axial mode of vibration may be reduced. In particular, the axial vibration may be significantly reduced.

In a conventional Herring-Bone magnet arrangement, the magnets are skewed relative to the axial direction, but the magnets are oriented parallel to each other. The conventional Herring-Bone configuration increases the mode of the axial exciting force/vibration from (1, 1) to (1, 2) in which the force vectors change directions twice along the axial length of each magnet pole. As a result of the mode increase or the increase of the order of the mode, the axial vibration may be reduced according to this conventional configuration.

However, even though the Herring-Bone skew configuration may reduce the axial vibration, the configuration according to the embodiment of the present invention may even further reduce the axial vibration. Further, the non-parallel arrangement of the adjacent first permanent magnet system and the second permanent magnet system may be combined with the Herring-Bone skew configuration, thereby increasing its effectiveness in reducing the axial vibration.

According to an embodiment of the present invention the circumferential distance increases continuously, in particular linearly, or in a step-wise manner from the first axial position to the second axial position. When the first permanent magnet system is constituted by a single integrally formed magnet, the circumferential distance may increase continuously. In particular, the increase of the circumferential distance may be linear with the axial position such that the circumferential distance may be calculated as a constant factor times the axial position plus a constant. In contrast, when the first permanent magnet system is constituted by plural individual permanent magnets the circumferential distance may increase in a step-wise manner. Thereby, a simple way to achieve the rotor arrangement may be provided.

According to an embodiment of the present invention the circumferential distance increases continuously, in particular

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linearly, or in a step-wise manner from the first axial position to a third axial position, wherein the distance decreases continuously, in particular linearly, or in a step-wise manner from the third axial position to the second axial position.

Thus, the circumferential distance increases between the first axial position and the third axial position and then decreases from the third axial position to the second axial position. Thereby, the Herring-Bone type configuration may be adapted according to the non-parallel arrangement of the first permanent magnet system and the second permanent magnet system according to an embodiment of the present invention. Thereby, the axial vibration may further be reduced.

According to an embodiment of the present invention the first permanent magnet system and the second permanent magnet system extend at the mounting surface across a same axial region.

Thus, in particular, the first permanent magnet system and the second permanent magnet system may be (immediately) adjacent along the circumferential direction and may span or occupy a same axial region which may be for example defined as the axial range between the first axial position and the second axial position. Alternatively, the first axial position and the second axial position may be somewhere in between limiting axial positions bordering the axial region. Mounting the first permanent magnet system and the second permanent magnet system at the same axial region may cause an effective cancelling out of (radial) force components when summing along the circumferential direction. Thereby, the reduction of the axial vibration may even further be improved.

According to an embodiment of the present invention the first permanent magnet system comprises at least a first part arranged at the first axial position and a second part arranged at the second axial position and/or wherein the second permanent magnet system comprises at least a first part arranged at the first axial position and a second part arranged at the second axial position.

According to this embodiment the first permanent magnet system comprises at least two (in particular a plurality of) parts arranged at different axial positions. Each part of the first permanent magnet system may represent or constitute a single individual permanent magnet, wherein the single permanent magnets are physically separated from each other and are not integrally formed but may constitute distinct physical elements.

Thereby, a so-called step-wise skew configuration may be achieved, while the first main extension direction and the second main extension direction are not parallel to each other. In particular, the first main extension direction may be defined as a straight line best fitting cross-sectional centers of the first part and the second part (or of the plural parts) of the first permanent magnet system and analogous definition is provided for the second permanent magnet system when comprising a first part and a second part (or plural parts constituting individual distinct permanent magnets).

Thereby, it may not be necessary to manufacture a single first permanent magnet for constituting the first permanent magnet system which may simplify the manufacturing the rotor arrangement.

According to an embodiment of the present invention the first permanent magnet system constitutes a single first magnet and/or wherein the second permanent magnet system constitutes a single second magnet.

Thereby, mounting the first permanent magnet system may be simplified, since it may not be necessary to mount plural parts of the first permanent magnet system. Further, orienting the first permanent magnet system at the mounting surface

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may be simplified, e.g. by aligning an edge of the first permanent magnet with a line drawn at the mounting surface, wherein this line is inclined relative (or is parallel) to the axial direction.

According to an embodiment of the present invention the single first magnet has a straight edge, in particular along its entire axial extent, and/or wherein the single second magnet has a straight edge, in particular along its entire axial extent. The magnet having a straight edge may be manufactured in a simple manner. Further, orienting the first magnet and the second magnet at the mounting surface may be simplified by aligning the straight edges with corresponding auxiliary lines drawn at the mounting surface.

According to an embodiment of the present invention the first magnet comprises a kink between a first section and a second sections, wherein the first section and the second section extend in a different directions, wherein in particular the first section is inclined relative to the axial direction in the circumferential direction, wherein in particular the second section is inclined relative to the axial direction in the opposite circumferential direction or runs along the axial direction, wherein in particular a non-parallel Herring-Bone type arrangement is achieved.

The first section of the first magnet may span a first axial region and the second section of the first magnet may span a second axial region adjacent to the first axial region. The kink may in particular be arranged at the third axial position. The first section may be arranged between the first axial position and the third axial position and the second section may be arranged between the third axial position and the second axial position.

Also a first sectional main extension direction may be assigned to the first section of the first magnet and a second sectional main extension direction may be assigned to the second section of the first magnet. In particular, the first sectional main extension direction and the second sectional main extension direction of the first magnet may not be parallel to each other. In particular, the first sectional main extension direction and the second sectional main extension direction of the first magnet may be inclined relative to the axial direction in an opposite fashion in which the inclination may be in the circumferential direction and in the opposite circumferential direction, respectively.

Thereby, a non-parallel Herring-Bone skew configuration may be achieved. Thereby, the axial vibration may further be reduced, when the rotor arrangement is assembled into an electromechanical transducer.

According to an embodiment of the present invention the first magnet system and the second magnet system have different magnetic orientations, in particular opposite magnetic orientations. For example, the first magnet system may have a north pole oriented radially inward and a south pole oriented or arranged radially outwards. The second magnet system may have the south pole oriented radially inward and the north pole oriented or arranged radially outwards. Thereby, the first magnet system and the second magnet system may in combination form a magnet pole pair.

According to an embodiment of the present invention the rotor arrangement further comprises a third permanent magnet system arranged at the mounting surface at a third circumferential region and a fourth permanent magnet system arranged at the mounting surface at a fourth circumferential region, wherein a circumferential distance between the third magnet system and the fourth magnet system at the first axial position differs from the circumferential distance between the first magnet system and the second magnet system at the second axial position, wherein a circumferential distance

between the second magnet system and the third magnet system at the first axial position differs from the circumferential distance between the second magnet system and the third magnet system at the second axial position.

In particular, the third permanent magnet system and the fourth permanent magnet system may constitute a further magnet pole pair being adjacent to the magnet pole pair constituted by the first permanent magnet system and the second permanent magnet system. The magnet pole pair and the further magnet pole pair may be (immediately) adjacent to each other in the circumferential direction.

In particular, the third permanent magnet system and/or the fourth permanent magnet system may have a same axial extent or may occupy a same axial region as the first permanent magnet system and/or the second permanent magnet system. The magnetic pole pair may be rotationally symmetry related to the further magnet pole pair, but does not need to be rotationally symmetry related.

In particular, when the magnet pole pair is rotationally symmetry related (with respect to the intended rotation axis of the rotor arrangement) to the further magnet pole pair the circumferential distance between the second magnet system and the third permanent magnet system may decrease from the first axial position to the second axial position. Further, the circumferential distance between the third permanent magnet system and the fourth permanent magnet system may increase from the first axial position to the second axial position. This configuration may in particular be achieved when the second magnet system is rotationally symmetry related around the axial direction to the fourth magnet system and when further the first magnet system is rotationally symmetry related around the axial direction to the third magnet system.

According to another embodiment of the present invention the second permanent magnet system may be rotationally symmetry related around the axial direction to the fourth permanent magnet system, but the first permanent magnet system may not be rotationally symmetry related around the axial direction to the third permanent magnet system. This may in particular be the case, when the second permanent magnet system is arranged to extend parallel to the axial direction and also when the fourth permanent magnet system is arranged to be parallel to the axial direction. In this configuration, the circumferential distance between the second permanent magnet system and the third permanent magnet system may increase (as the circumferential distance between the first permanent magnet system and the second permanent magnet system) from the first axial position to the second axial position. However, the circumferential distance between the third permanent magnet system and the fourth permanent magnet system may decrease from the first axial position to the second axial position. This configuration is in particular provided, when the first permanent magnet system is not rotationally symmetry related around the axial direction to the third permanent magnet system.

In particular, according to this last embodiment it may be avoided to reduce the width of the magnet systems too much, thereby increasing the efficiency of the electromechanical transducer, in particular the generator output energy. In particular, it may be avoided that edges of neighbouring permanent magnet systems approach each other.

According to an embodiment of the present invention it is provided an electromechanical transducer, in particular a generator which comprises a stator having plural teeth having a slot between adjacent teeth and a rotor arrangement according to one of the embodiments described above. In operation vibration of the electromechanical transducer may be reduced

due to the particular constitution of the rotor arrangement having non-parallel adjacent permanent magnets.

According to an embodiment of the present invention the skew angle (or skew angles) defining the orientation or orientation of the permanent magnet systems with respect to the axial direction is selected to reduce axial vibration during operation of the transducer. Finding the optimal skew angle may be a compromise between maximizing the width of the permanent magnet system (in particular circumferential width) (requiring decreasing the skew angle) and reducing the undesired vibrations or vibration modes (requiring increasing the skew angle). Simulations (in particular taking into account the geometry, used materials and intended operation conditions of the transducer) may be performed, in order to determine the optimized skew angle, on one hand improving the efficiency or energy output of the electromechanical transducer and on the other hand reducing vibrations leading to undesired noise emissions.

According to an embodiment of the present invention the electromechanical transducer is configured as a generator. The generator may be comprised in a wind turbine and may be mechanically connected to a main shaft of the wind turbine at which plural rotor blades are connected.

Particular embodiments of the present invention are now described with reference to the accompanying drawings. The invention is not limited to the described or illustrated embodiments.

The aspects defined above and further aspects of the present invention are apparent from the examples of embodiment to be described hereinafter and are explained with reference to the examples of embodiment. The invention will be described in more detail hereinafter with reference to examples of embodiment but to which the invention is not limited.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically illustrates a perspective view of a rotor arrangement according to an embodiment of the present invention;

FIG. 2 schematically illustrates a perspective view of a portion of an electromechanical transducer according to an embodiment of the present invention for definition of parameters;

FIG. 3 schematically illustrates a schematic view of a radial projection of a portion of a rotor arrangement according to an embodiment of the present invention;

FIG. 4 schematically illustrates a schematic view of a radial projection of a portion of a rotor arrangement according to an embodiment of the present invention;

FIG. 5 schematically illustrates a schematic view of a radial projection of a portion of a rotor arrangement according to an embodiment of the present invention; and

FIG. 6 schematically illustrates a schematic view of a radial projection of a portion of a rotor arrangement according to an embodiment of the present invention.

DETAILED DESCRIPTION OF INVENTION

FIG. 1 illustrates a perspective view of a rotor arrangement 100 according to an embodiment of the present invention. The rotor arrangement 100 comprises a support structure 101, which provides a mounting surface 103 extending in an axial direction 105 and in a circumferential direction 107, wherein the support structure is intended to be rotated around a rotation axis 109 which runs along the axial direction 105. In particular, the support structure 101 is circular in shape and

has a cylindrical configuration. The radial direction **108** is indicated in FIG. **1** as pointing from the center **110** of the circle **112** outwards towards the mounting surface **103** of the support structure **101**.

The rotor arrangement **100** comprises a first permanent magnet system **111** which is mounted at the mounting surface **103** at a first circumferential region **113**. Further, the rotor arrangement **100** comprises a second permanent magnet system **115** which is arranged at the mounting surface **103** at a second circumferential region **117**. In particular, the first permanent magnet system **111** is adjacent to the second permanent magnet system **115**.

A first circumferential distance **119** between the first permanent magnet system **111** and the second permanent magnet system **115** at a first axial position **121** (along a line **123** running in the axial direction **105** or at least being parallel to the rotation axis **109**) differs from a second circumferential distance **125** between the first permanent magnet system **111** and the second permanent magnet system **115** at a second axial position **127**.

In particular, the circumferential distance **121** is smaller than the circumferential distance **125** such that the first permanent magnet system **111** is non-parallel to the second permanent magnet system **115**. In particular, the first permanent magnet system is comprised of a single permanent magnet having a first main extension direction **129** and also the second permanent magnet system **115** is constituted by a single permanent magnet having a second main extension direction **131**. The first main extension direction **129** may be constructed or defined as a best fitting line through cross-sectional centers (either geometrical centers or magnetic centers or mass centers) of the first permanent magnet system **111**. Further, the second main extension direction of the second permanent magnet system **115** may be defined or constructed as a best fitting line through plural cross-sectional centers (either geometrical centers or magnetic centers or mass centers) of the second permanent magnet system **115**.

As is apparent from FIG. **1** the first main extension direction **129** of the first permanent magnet system **111** deviates from the axial direction **105** by an angle Φ_1 and the second main extension direction **131** deviates from the axial direction **105** by the skew angle Φ_2 . In particular, the angles Φ_1 , Φ_2 are inclined relative to the axial direction **105** in an opposite way ($\Phi_1 = \Phi_2$), thereby causing the different circumferential distances between the first permanent magnet system **111** and the second permanent magnet system **115** at the first axial position **121** and the second axial position **127**, respectively. The rotor arrangement **100** comprises further permanent magnet systems which are evenly distributed along the circumferential direction **107** at the mounting surface **103** which, however, are not illustrated in FIG. **1**.

The rotor arrangement **100** may for example be used as an outer rotor in an electrical generator which is in particular employed in a wind turbine.

FIG. **2** illustrates a schematic perspective view representing a portion of a generator **200**, in particular using the rotor arrangement **100** illustrated in FIG. **1**. The generator **200** illustrated in FIG. **2** comprises the rotor arrangement **100** illustrated in FIG. **1** and further a stator portion **250** comprising a yoke **251** having plural teeth **253** for forming slots **255** between adjacent teeth **253**. The distance between adjacent teeth **253** (i.e. the tooth pitch) is denoted as τ_g , as is indicated in FIG. **2**. Around the teeth, i.e. within the slots **255** wires are wound for forming coils which are, however, not illustrated in FIG. **2**.

The first permanent magnet system **111** and the second permanent magnet system **115** together form a magnet pole pair. The width of the first permanent magnet system **111** is indicated as w .

In FIG. **2** also the axial direction **105**, the circumferential direction **107** and the radial direction **108** are indicated. The first permanent magnet system **111** has its north pole **141** arranged radially outwards from its south pole **132** and the second permanent magnet system **115** has its south pole **133** radially positioned outwards from its north pole **134**. The quantity τ_p indicated in FIG. **2** is also called the pole pitch relating not to the physical extent of the magnetic system (which is denoted as w) but relating to the magnetic extent of the magnet system in the circumferential direction **107**. In particular, the period of the magnetic field generated by the first permanent magnet system and the second permanent magnet system **115** corresponds to two times τ_p .

In FIGS. **3** to **6** an element or a structures which is similar in structure and/or functions to an element illustrated in FIG. **1** is denoted with same reference sign differing only in the first digit. Description of these corresponding elements can therefore be taken from the description of the corresponding elements described with reference to FIG. **1**.

FIG. **3** schematically illustrates a view of a projection in the radial direction **208** of a rotor arrangement **200** according to an embodiment of the present invention.

The rotor arrangement **200** comprises a first permanent magnet **211** having a first main extension direction **229**, which is inclined relative to the axial direction by an angle Φ_1 . Further, the rotor arrangement **200** comprises a second permanent magnet **215** having a second main extension direction **231** which is inclined relative to the axial direction **205** by an angle Φ_2 . Further, the rotor arrangement **300** comprises a third permanent magnet **235** having a main extension direction **236** which is inclined relative to the axial direction **205** by an angle Φ_3 . Further, the rotor arrangement **300** comprises a fourth permanent magnet **237** having a main extension direction **238** which is inclined relative to the axial direction **205** by an angle Φ_4 .

Thereby, a first circumferential distance **219** between the first permanent magnet **211** at a first axial position **221** is smaller than a circumferential distance **225** between the first permanent magnet **211** and the second permanent magnet **215** at a second axial position **227**. Further, according to this embodiment illustrated in FIG. **3** the circumferential distance **219** equals or corresponds to a circumferential distance between the second permanent magnet **215** and the third permanent magnet **235** at the second axial position **227** and also the circumferential distance **219** equals or corresponds to the circumferential distance between the third permanent magnet **235** and the fourth permanent magnet **237** at the first axial position **221**.

Further, as can be seen from FIG. **3**, the circumferential distance **219** at the first axial position **221** increases linearly to the circumferential distance **225** at the second axial position **227**.

Further, the circumferential distance **225** corresponds or equals to the circumferential distance between the second permanent magnet **215** and the third permanent magnet **235** at the first axial position **221**. Further, the circumferential distance **225** equals or corresponds to the circumferential distance between the third permanent magnet **235** and the fourth permanent magnet **237** at the second axial position **227**.

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In particular, the magnet pole pair formed by the first permanent magnet **211** and the second permanent magnet **215** is rotationally symmetry related to the further magnet pole pair formed by the third permanent magnet **235** and the fourth permanent magnet **237**.

In FIG. **3** the indicated forces $F_1, F_2, F_3, F_4, F_5, F_6, F_7$ and F_8 denote forces during operation of the rotor arrangement **200** used in an electromechanical transducer, wherein the forces F_1, F_3, F_6 and F_8 denote forces directed radially outwards, while the forces F_2, F_4, F_5 and F_7 denote forces pointing radially inwards. As is apparent from the illustrated forces in FIG. **3** the forces acting on a single magnet system cancel out, e.g. the forces F_1 (pointing radially outward) and F_5 (pointing radially inwards) act on the first permanent magnet **211**, thus result in a net force of zero.

Further, as is apparent from FIG. **3** forces acting at a particular axial position (for example between the position **221** and **227** denoting the first axial position and second axial position, respectively) are in sum zero, thus cancel out each other when summing along the circumferential direction **207** (e.g. the sum of F_1, F_2, F_3, F_4 is zero). Thereby, axial vibration may be reduced.

In particular, the angles are $\Phi_1 = -\Phi_2$ and $\Phi_3 = -\Phi_4$ and $\Phi_1 = \Phi_3$. Thus, the skew angles have alternately changing signs. Thereby, the force vector F_1 - F_8 balance out in the circumferential direction **207** as well as in the axial direction **205**. In other words, the axial vibration mode may change from (1, 1) in a conventional skew to (2P, 1) in the proposed non-parallel skew, where P is the number of magnet poles in the complete rotor arrangement. Since the achieved mode of axial vibration based on the embodiment of the present invention is much larger than that obtained from a conventional Herring-Bone skew, it is realized that the damping of axial vibration obtained by the non-parallel skew may be much more significant or effective.

By skewing the magnet following the proposed non-parallel arrangement the edge of the magnets may become closer together at one end and farther apart from each other at the other end. Usually, the ratio w/τ_p , as illustrated in FIG. **2**, should generally be chosen to be very high to give maximum generator output. However, the non-parallel arrangement of adjacent permanent magnet as illustrated for example in FIG. **3** or in FIGS. **4** to **6**, may impose a limitation to the ratio w/τ_p in order to avoid collision of the edges of adjacent magnets. Thereby, the generator output may be reduced.

However, by appropriate simulation an optimal compromise between maximizing the width w and avoiding undesired vibrations may be obtained.

Further, in order to reduce the limiting effect or limiting factor and in order to keep the width w as large as possible a configuration as illustrated in FIG. **4** (or FIG. **6**) is proposed. The rotor arrangement **300** illustrated in FIG. **4** (also as a radial projection in a schematic way) comprises the first permanent magnet **311** inclined relative to the axial direction **305** by the angle Φ_1 , the second permanent magnet **315** having its main extension direction **331** aligned with and thus parallel to the axial direction **305**, a third permanent magnet **335** having its main extension direction **336** inclined by an angle Φ_3 relative to the axial direction, and the fourth permanent magnet **337** having its main extension direction **338** aligned parallel to the axial direction **305**. Further, in this embodiment $\Phi_1 = -\Phi_3$. Thereby, the width w of the permanent magnet may be increased while still reducing undesired vibrations.

FIG. **5** illustrates a rotor arrangement **400** in a radial projection according to an embodiment of the present invention. The rotor arrangement **400** comprises a first permanent magnet **411**, a second permanent magnet **415**, a third permanent

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magnet **435** and a fourth permanent magnet **437**, which are arranged at a same axial region between the first axial position **421** and the second axial position **427**. All permanent magnets **411**, **415**, **435**, **437** illustrated in FIG. **5** comprise a first section and a second section, wherein the first section is arranged between the first axial position **421** and the third axial position **422** and the second section is arranged between the third axial position **422** and the second axial position **427**.

For clarity only the first section **439** and the second section **441** of the first permanent magnet **411** are illustrated in FIG. **5**. Between the first section **439** and the second section **441** of the first permanent magnet **411** a kink **443** is provided, at which the extension direction changes. In particular, the first section **439** extends along a main extension direction **445** which is inclined relative to the axial direction **405** by an angle Φ_{11} . Further, the main extension direction **446** of the second section **441** of the first magnet **411** is inclined relative to the axial direction **405** by an angle Φ_{12} , wherein $\Phi_{11} = -\Phi_{12}$.

The second permanent magnet **415** has an arrangement resembling a mirror image of the first permanent magnet **411**, wherein a (virtual) mirror plane **447** (extending in the axial direction **405** and the radial direction **408**) is arranged between the first permanent magnet **411** and the second permanent magnet **415**.

Further, the circumferential distance between the first permanent magnet **411** and the second permanent magnet **415** increases between the first axial position **421** and the third axial position **422** from the value **419** and **425** and then decreases from the third axial position **422** to the second axial position **427** to become the distance **419** again. Thereby, the circumferential distance between two permanent magnets may be measured between edges of the permanent magnet or between respective main extension directions.

The third permanent magnet **435** and the fourth permanent magnet **437** are rotationally symmetry related to the first permanent magnet **411** and the second permanent magnet **415**.

FIG. **6** schematically illustrates a rotor arrangement **500** comprising a first permanent magnet **511**, a second permanent magnet **515**, a third permanent magnet **535** and a fourth permanent magnet **537**. The first permanent magnet **511** has a same configuration as the first permanent magnet **411** of the embodiment illustrated in FIG. **5**. Further, the second permanent magnet **515** has the same configuration and arrangement as the second permanent magnet **315** illustrated in FIG. **4**. Thereby, in particular a width w of the permanent magnet may be increased, while maintaining reduction of undesired vibration modes.

All permanent magnets illustrated in FIGS. **3** to **6** may also be constituted from plural individual distinct magnets which are arranged side by side along the axial direction or along the respective main extension direction. Thereby, the circumferential distance between two neighbouring permanent magnet systems may in particular change in a step-wise manner. According to another embodiment the permanent magnet may comprise more than one kink such that for example the permanent magnets comprise plural axial sections having alternating main extension directions, thereby forming a zig-zag structure.

It should be noted that the term "comprising" does not exclude other elements or steps and "a" or "an" does not exclude a plurality. Also elements described in association with different embodiments may be combined. It should also be noted that reference signs in the claims should not be construed as limiting the scope of the claims.

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The invention claimed is:

1. A rotor arrangement, comprising:

a support structure providing a mounting surface extending in an axial direction and a circumferential direction, the support structure being adapted to rotate around the axial direction;

a first permanent magnet system arranged at the mounting surface at a first circumferential region; and

a second permanent magnet system arranged at the mounting surface at a second circumferential region;

wherein a circumferential distance between the first magnet system and the second magnet system at a first axial position differs from the circumferential distance between the first magnet system and the second magnet system at a second axial position;

wherein the first permanent magnet system is inclined with respect to the axial direction in the circumferential direction between the first axial position and the second axial position; and

wherein the second permanent magnet system is inclined with respect to the axial direction in an opposite circumferential direction between the first axial position and the second axial position;

wherein the first permanent magnet system comprises a first magnet and the first magnet comprises a kink between a first section and a second sections; and

wherein the first section and the second section extend in different directions inclined relative to the axial direction.

2. The rotor arrangement according to claim 1, wherein the circumferential distance increases continuously or in a step-wise manner from the first axial position to the second axial position.

3. The rotor arrangement according to claim 1, wherein the circumferential distance increases continuously or in a step-wise manner from the first axial position to a third axial position,

wherein the distance decreases continuously or in a step-wise manner from the third axial position to second axial position.

4. The rotor arrangement according to claim 1, wherein the first permanent magnet system and the second permanent magnet system extends at the mounting surface across a same axial region.

5. The rotor arrangement according to claim 1, wherein the first permanent magnet system comprises at least a first part arranged at the first axial position and a second part arranged at the second axial position, and/or

wherein the second permanent magnet system comprises at least a first part arranged at the first axial position and a second part arranged at the second axial position.

6. The rotor arrangement according to claim 1, wherein the second permanent magnet system constitutes a single second magnet.

7. The rotor arrangement according to claim 6, wherein the first magnet has a straight edge, in particular along its entire axial extent, and/or

wherein the single second magnet has a straight edge, in particular along its entire axial extent.

8. The rotor arrangement according to claim 6, wherein the first section is inclined relative to the axial direction in the circumferential direction.

9. The rotor arrangement according to claim 6, wherein the second section is inclined relative to the axial direction in the opposite circumferential direction or runs along the axial direction.

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10. The rotor arrangement according to claim 6, wherein a non-parallel Herring-Bone type arrangement is achieved.

11. The rotor arrangement according to claim 1, wherein the first magnet system and the second magnet system have different magnetic orientations.

12. The rotor arrangement according to claim 1, further comprising:

a third permanent magnet system arranged at the mounting surface at a third circumferential region;

a fourth permanent magnet system arranged at the mounting surface at a fourth circumferential region;

wherein a circumferential distance between the third magnet system and the fourth magnet system at the first axial position differs from the circumferential distance between the first magnet system and the second magnet system at the second axial position,

wherein a circumferential distance between the second magnet system and the third magnet system at the first axial position differs from the circumferential distance between the second magnet system and the third magnet system at the second axial position.

13. The rotor arrangement according to claim 12, wherein the second magnet system has rotational symmetry related around the axial direction to the fourth magnet system.

14. The rotor arrangement according to claim 12, wherein the first magnet system has rotational symmetry related around the axial direction to the third magnet system.

15. An electromechanical transducer, comprising:
a stator having plural teeth having a slot between adjacent teeth;

a rotor arrangement according to claim 1.

16. The electromechanical transducer according to claim 15, wherein a skew angle is selected to reduce axial vibration during operation of the transducer.

17. A rotor arrangement comprising: a support structure providing a mounting surface extending in an axial direction and a circumferential direction, the support structure being adapted to rotate around the axial direction;

a first permanent magnet system arranged at the mounting surface at a first circumferential region; and

a second permanent magnet system arranged at the mounting surface at a second circumferential region;

wherein a circumferential distance between the first magnet system and the second magnet system at a first axial position differs from the circumferential distance between the first magnet system and the second magnet system at a second axial position;

wherein the first permanent magnet system is inclined with respect to the axial direction in the circumferential direction between the first axial position and the second axial position;

wherein the second permanent magnet system is inclined with respect to the axial direction in an opposite circumferential direction between the first axial position and the second axial position; further comprising:

a third permanent magnet system arranged at the mounting surface at a third circumferential region;

a fourth permanent magnet system arranged at the mounting surface at a fourth circumferential region;

wherein a circumferential distance between the third magnet system and the fourth magnet system at the first axial position differs from the circumferential distance between the first magnet system and the second magnet system at the second axial position,

wherein a circumferential distance between the second magnet system and the third magnet system at the first axial position differs from the circumferential dis-

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tance between the second magnet system and the third magnet system at the second axial position; and wherein the first magnet system is not rotationally symmetric related around the axial direction to the third magnet system.

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